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Veltman, D.J.; de Ruiter, M.B.; Rombouts, S.A.R.B.; Lazeron, R.H.; Barkhof, F.; van Dyck, R.; Dolan, R.J.; Phaf, R.H

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Neurophysiological correlates of increased verbal working memory in high-dissociative participants: a functional MRI study

DICK J. VELTMAN, MICHIEL B. DE RUITER*, SERGE A. R. B. ROMBOUTS, RICHARD H. C. LAZERON, FREDERIK BARKHOF, RICHARD VAN DYCK, RAYMOND J. DOLAN AND R. HANS PHAF

Department of Psychiatry & Clinical PET Center; *Department of Physics and Medical Technology*; *Department of Neurology*; *Department of Radiology*; *Vrije Universiteit Medical Center*, *Amsterdam*; *Psychonomics Department*, *University of Amsterdam*; *Department of Psychiatry*, *p/a Valeriuskliniek*, *Amsterdam*, *The Netherlands*; *Wellcome Department of Cognitive Neurology*, *Institute of Neurology*, *London*, *UK*; *Faculty of Social and Behavioral Sciences*, *Psychonomics Department*, *University of Amsterdam*, *The Netherlands*

ABSTRACT

Background. Dissociation, defined as a disruption in usually integrated mental functions, is found not only in DSM-IV dissociative disorders, but also in post-traumatic stress disorder and eating disorders. Dissociative phenomena are also common in the general population, and may reflect a constitutionally determined cognitive style rather than a pathological trait acquired through experiencing adverse life events. In pathological dissociation, evidence has been presented for episodic memory dysfunction. In contrast, in high-dissociative subjects increased performance has been found for episodic memory and dual task performance. These findings have been linked to changes in working memory capacity.

Method. In the present study, the authors sought to extend these findings by using functional magnetic resonance imaging during performance of two parametric working memory tasks. We tested 21 healthy low- and high-dissociative participants.

Results. High-dissociative participants performed slightly better during both tasks. Imaging data showed that both groups activated similar networks for both tasks, i.e. (bilateral) dorsolateral (DL) and ventrolateral prefrontal cortex (PFC), parietal cortex, and supplementary motor area. Group × task interactions were found in the high-dissociative group in L DLPFC and L parietal cortex; in the low-dissociative group in R fusiform gyrus. The differences in the high-dissociative group were independent from performance differences, implying that high-dissociative subjects generally recruit this network to a greater extent.

Conclusions. These results confirm earlier findings using a verbal WM task in high-dissociative participants, and are compatible with the conceptualization of non-pathological dissociation as an information-processing style, characterized by distinct attentional and mnemonic abilities.

INTRODUCTION

Dissociation, a term coined by Janet in the early 1900s (Janet, 1907), refers to a disruption of usually integrated functions of consciousness, memory, identity, or perception of the environment. In dissociative disorders, such as dissociative identity disorder (DID), mental functions may be disintegrated so severely that two or more distinct identities or personality states (i.e. 'alters') recurrently take control of behaviour (DSM-IV; APA, 1994). Dissociative

* Address for correspondence: Michiel B. de Ruiter, Faculty of Psychology, Department of Clinical Neuropsychology, Vrije Universiteit, Van der Boechorststraat 1, 1081 BT Amsterdam, The Netherlands.
(Email: mb.de.ruiter@psy.vu.nl)

phenomena are not unique to dissociative disorders, but may also occur in acute stress disorder (Spiegel *et al.* 1996; Morgan *et al.* 2001), post-traumatic stress disorder (Boon & Draijer, 1993), and eating disorders (Vanderlinden *et al.* 1993*a*). In addition, dissociative experiences are common in the general population (Ross *et al.* 1990; Vanderlinden *et al.* 1991; Kihlstrom *et al.* 1994; Putnam *et al.* 1996). The aetiology of dissociative phenomena is insufficiently known. Dissociative amnesia [defined as an inability to recall important personal information that is too extensive to be explained by ordinary forgetfulness (APA, 1994)], considered to be a key symptom of pathological dissociation, has been explained as resulting from traumatic experiences, such as severe physical (Mulder *et al.* 1998) and sexual (Chu *et al.* 1999) abuse, particularly during childhood (Bliss, 1986; Kluft, 1986; Putnam *et al.* 1986; Gleaves, 1996). This assumption has been strongly contended, however, by the sociocognitive model, which conceptualizes 'alters' in terms of cultural scripts that are shaped by psychotherapists, media portrayals and sociocultural expectations (Spanos, 1994; Brewin & Andrews, 1998; Merckelbach & Muris, 2001). Both positions acknowledge the existence of individual differences in dissociative style (i.e. the tendency to disintegrate consciousness, memory, or perceptual functions). The high level of genetic influences in both pathological and non-pathological dissociation, and the substantial shared genetic variance (Jang *et al.* 1998), moreover, suggests that a fundamental mechanism may be involved that acts, initially at least, independently of adverse life experiences. This study aims to contribute to the characterization of dissociative style in terms of cognitive and neural information-processing mechanisms, in particular working memory, in a group of non-clinical participants.

Cognitive experimental research in dissociative disorders has focused on memory dysfunction, in particular impairment of episodic memory between alter personalities (Eich *et al.* 1997; Peters *et al.* 1998; Dorahy, 2001), whereas performance on a standard intelligence test is apparently not different from matched controls (Rossini *et al.* 1996). In contrast, there are also indications, at least in some conditions, of *enhanced* memory performance in patients with highly dissociative tendencies (Cloitre *et al.* 1996; McNally *et al.* 1998, 2001; Elzinga *et al.* 2000). This form of 'hypermnesia' has, however, only been observed when encoding and retrieval take place in the same personality state. Elzinga *et al.* (2000), using a directed forgetting paradigm, explained the superior memory performance of their high-dissociative participants as due to increased elaboration, for which a high working memory (WM) capacity is a prerequisite. In contrast, Dorahy (2001) hypothesized WM deficits in high-dissociative subjects, resulting in increased interference in a classical Stroop task (i.e. naming the colour of the letters of colour words) owing to a failure to keep working memory free of irrelevant stimuli (Freyd *et al.* 1998). In the same vein, Conway *et al.* (2001) showed that participants who demonstrate the 'cocktail party phenomenon' (i.e. are able to detect their name in an unattended, irrelevant message), have a relatively low working-memory capacity.

In a recent study, de Ruiter *et al.* (in press) administered both a questionnaire measuring dissociative tendencies (Dis-Q; Vanderlinden *et al.* 1993*b*) and a Dutch version of the verbal working memory span test (Daneman & Carpenter, 1980) to 119 participants in three unrelated experiments. Participants with a Dis-Q score approaching pathological ranges had a verbal span that was on average half a word larger than participants with lower scores. Although these latter findings are in agreement with the elaboration hypothesis of Elzinga *et al.* (2000), the memory test used by de Ruiter and co-workers presumably does not provide the most accurate estimate of verbal working memory capacity. It has been argued recently that 'pure' working memory span is likely to be considerably less than seven, as postulated by Miller (1956), particularly when rehearsal is blocked, for instance by having participants perform a distracter task (Cowan, 2001). If the number of study items is large, participants may resort to alternative encoding strategies, such as forming associations between items, or remembering the order in which items were presented (Rypma & D'Esposito, 1999). When, on the other hand, rehearsal is possible, WM capacity is likely to be determined by the number of items that can be rehearsed in about 2 s (Baddeley, 1996; Cowan, 2001).

Consequently, consonant letter strings are preferable to words or objects to avoid confounds arising from the use of complex stimuli.

A second issue regarding WM function is the distinction made in the literature between manipulation and maintenance tasks. Maintenance has been defined as transferring, maintaining (including rehearsal), and matching of information in WM (Fletcher & Henson, 2001), whereas manipulation refers to the additional reorganization or updating of each memory set. It has been argued that these functions depend on neuro-anatomically distinct areas within the prefrontal cortex (PFC), i.e. ventrolateral PFC (maintenance) and dorsolateral PFC (manipulation). Whereas maintenance tasks can be used to test WM span, manipulation WM tasks require additional executive functions similar to dual task performance (Baddeley, 1996; D'Esposito *et al*. 1995), which may solely be enhanced in high-dissociators (Freyd *et al*. 1998; De Ruiter *et al*. 2003).

In the present study, we aimed to extend our previous findings with regard to WM function in high- *versus* low-dissociative participants. To this end, we used functional magnetic resonance imaging (fMRI) to compare high- and low-dissociative participants during performance of two WM tasks, one maintenance task (Sternberg task) and one manipulation task (*n*-letter-back task). Both tasks employed letter stimuli (consonants only), in order to avoid long-term memory encoding strategies to support maintenance, as outlined earlier. In addition, both tasks were varied parametrically, enabling us to identify regions specifically associated with task performance (Jansma *et al*. 2000). Given our previous findings using a WM span task, we expected that high-dissociative participants would perform better during a maintenance WM task, particularly at higher task loads. If, however, only increased executive functions are involved in dissociation, such an advantage would only be expected in the manipulation WM task.

METHOD

Participants

Participants were selected on the basis of their scores on the Dissociative Symptoms Questionnaire (Dis-Q; Vanderlinden *et al*. 1993*b*) which was administered in a general 'test week' (in exchange for course credit) to approximately 400 first-year students in the Psychology Department of the University of Amsterdam. The Dis-Q is a 63-item self-reporting scale for dissociative experiences using a 5-point Likert scale (1 = not at all, 5 = extremely). In the general population, it has been shown that dissociation scores are highly left-skewed, with no differences between males and females (Ross & Ryan, 1989; Vanderlinden *et al*. 1991). For the present fMRI study, persons scoring in the highest and lowest quartiles were contacted for participation. Twenty-two healthy right-handed students participated in the study. All gave informed consent after the rationale of the study had been explained, and were paid for their participation. The experimenter did not know the participant's Dis-Q score during the experiment. In order to obtain an estimate of the participant's passive vocabulary, a vocabulary test was administered (Elshout, 1976). This multiple choice test consists of 40 low-frequency words of which the right synonym or description has to be chosen.

Task paradigms

Prior to scanning, all participants practised both tasks outside the scanner on a personal computer. To account for possible differences in state anxiety, participants were asked to rate their subjective distress on a 100-point scale (SUD-S; 0 = not at all distressed, 100 = extremely distressed) before each time series while in the scanner.

N-letter-back

The four-step parametric version of the *n*-letter-back task employed in this study was similar to the Braver *et al*. (1997) paradigm. Participants saw single letters projected on a screen and were requested to press a (right-hand) response key when (1) the letter 'x' appeared (baseline), (2) the projected letter was the same as the last shown letter (1-back), (3) the projected letter was the same as the letter preceding the last shown letter (2-back), and (4) the projected letter was the same as the letter preceding the last two shown letters (3-back). Each *n*-back session consisted of two subsessions, in which all conditions were presented twice, in pseudo-randomized order.

Each block consisted of 20 stimuli with an inter stimulus interval (ISI) of 3 s and was preceded by a condition-specific instruction (6 s).

Sternberg

We used a six-step parametric version of the letter Sternberg task. In each condition, participants were instructed to memorize a letter string of varying length (2–7 letters) during 10 s, after which the string disappeared and single letters were projected on a screen. Participants were requested to press (right-hand) one of two keys to indicate whether the letter had been in the string (Y/N). Each letter string was followed by 15 single letters (ISI = 2·5 s), and each block was introduced by the text 'New string will follow' (*nieuwe reeks volgt*) presented for 5 s. Each condition was repeated three times, giving 18 blocks, in randomized order.

Scanning details

Functional MRI was performed at the Department of Radiology of the outpatient clinic of the Vrije Universiteit Academic Hospital, using a 1.5 Tesla Vision whole-body system (Siemens AG, Erlangen, Germany) equipped with a head-volume coil. Axial multislice T_2*-weighted images were obtained with a gradient-echo planar sequence (TE = 60 ms, TR = 3·485 s, 64×64 matrix, 32 slices, 3×3 mm in-plane resolution, slice thickness 3 mm with a 1 mm interslice gap), covering the entire brain. Each session consisted of two fMRI subsessions during which 2×153 (*n*-back) and 280 (Sternberg) volumes were acquired, with the two tasks in counterbalanced order across participants. Between the subsessions, a T_1-weighted structural 3D gradient-echo MR scan ($0{\cdot}78 \times 0{\cdot}78 \times 2$ mm voxel size) was acquired.

Statistical analysis

Overall performance [error rates, i.e. the ratio (number of correct responses/total number of responses × 100 %), reaction times, and SUD-S scores] was assessed with a standard statistical package by analyses of variance (ANOVAs) with a mixed factorial design; group differences were assessed by comparing error rates and reaction times for difficult *versus* easy steps (string length 2–4 compared with 5–7 in the Sternberg; conditions X and 1-back compared with 2- and 3-back in the *n*-back). Imaging data were analysed with SPM99 (ION, 2004). After discarding the first two scans of each time series to allow for a steady state to be induced, images were realigned, and spatially normalized into the standard space of Talairach & Tournoux (1988) using each subject's co-registered structural T_1 scan. The data were smoothed spatially with an 8-mm isotropic Gaussian kernel. Subsequently, data were band-pass filtered, and analysed in the context of the General Linear Model, using boxcar regressors convolved with the canonical haemodynamic response to model responses during each condition. For each task, linear contrasts were computed for main effects of task load for each subject. The resulting contrast images were then fed into a second-level (random effects) analysis and main effects for task load were assessed for each group, as well as group × task-load interactions. Main effects for each group are reported at $p < 0{\cdot}005$ corrected for multiple comparisons using the False Discovery Rate method (Genovese *et al.* 2002), with a cluster size restriction of 10 voxels. Interaction effects are reported at $p < 0{\cdot}001$ uncorrected, masked with the appropriate main effect at $p < 0{\cdot}001$.

RESULTS

One scanning session (involving a female participant from the high-dissociative group) was aborted due to intervening panic. Consequently, the low dissociative group consisted of 10 participants (Dis-Q score $1{\cdot}33 \pm 0{\cdot}03$, age $22{\cdot}9 \pm 1{\cdot}27$, seven females) and the high dissociative group consisted of 11 participants (Dis-Q score $2{\cdot}24 \pm 0{\cdot}11$, age $22{\cdot}6 \pm 1{\cdot}03$, seven females). Scores on the vocabulary test could be collected for all low dissociators (number of correct answers $16{\cdot}00 \pm 1{\cdot}74$) and for 9 of 11 high dissociators (number of correct answers $17{\cdot}89 \pm 1{\cdot}56$). Not surprisingly, Dis-Q scores differed significantly for the two groups [$t(19) = 7{\cdot}97$, $p < 0{\cdot}000001$], whereas age [$t(19) < 1$, N.S.] and vocabulary [$t(19) < 1$, N.S.] were about the same for both groups.

Analysis of behavioural data (ANOVA) showed for both task-load-related increases in reaction times [for *n*-back: $0{\cdot}55\ \text{s} \pm 0{\cdot}078$ (baseline)–$0{\cdot}84\ \text{s} \pm 0{\cdot}24$ (3-back), $F(3, 17) = 14{\cdot}1$, $p < 0{\cdot}001$; for Sternberg: $0{\cdot}66\ \text{s} \pm 0{\cdot}09$ (string length 2)–$0{\cdot}92\ \text{s} \pm 0{\cdot}12$ (string length 7),

Table 1. *Areas showing significant ($p<0{\cdot}005$ corrected, extent threshold >10 voxels) linear task-load-related increase in activity during performance of the Sternberg task in high- and low-dissociative subjects*

	High-dissociation group ($n=10$)			Low-dissociation group ($n=11$)		
Region	Talairach coordinates	*Z* score	BA	Talairach coordinates	*Z* score	BA
L prefrontal						
Dorsolateral	−48, 30, 33	4·4	9			
	−48, 24, 30	4·4	9	−48, 24, 30	4·7	9
	−42, 27, 21	4·0	46	−51, 21, 33	4·9	9
	−45, 12, 36	5·6	44	−48, 12, 36	4·6	44
	−39, 9, 30	5·6	44	−51, 12, 24	4·4	44
Ventrolateral	−54, 15, 6	4·7	44	−54, 15, 6	5·0	44
R prefrontal						
Anterior	33, 45, 18	3·9	10			
Dorsolateral	45, 36, 33	4·1	9			
	54, 15, 36	4·2	44			
L parietal	−39, −42, 45	4·0	40			
	−36, −51, 54	4·6	40	−30, −54, 36	4·5	40
R parietal	27, −63, 39	4·0	40			
L inferior temporal	−45, −51, −12	4·0	37	−39, −51, −12	4·6	37
R fusiform gyrus				15, −63, −9	4·2	19
Anterior cingulate gyrus	9, 30, 36	5·4	32	9, 24, 45	4·1	32
SMA	2, 16, 63	5·5	6	24, 0, 60	4·6	6
Cerebellum	−21, −69, −33	3·9		−21, −63, −39	4·1	
	39, −51, −42	4·6		9, −30, −36	4·2	

BA, Brodmann area; SMA, supplementary motor area.

$F(5, 15)=18{\cdot}1$, $p<0{\cdot}001$]. Overall performance for both tasks was high (for the *n*-back, $97{\cdot}7\% \pm 1{\cdot}7$; for the Sternberg $94{\cdot}7\% \pm 2{\cdot}2$), although performance decreased with increasing task load [*n*-back: $F(3, 17)=4{\cdot}7$, $p=0{\cdot}017$; Sternberg: $F(5, 15)=30{\cdot}0$, $p<0{\cdot}001$]. Sternberg task performance, defined as the mean difference between scores for easy (string length 2–4) and difficult items (string length 5–7) was better in the high-dissociative group than in the low-dissociative group [$9{\cdot}6 \pm 4{\cdot}9$ *v.* $5{\cdot}3 \pm 4{\cdot}2$; $F(1, 19)=4{\cdot}7$, $p=0{\cdot}043$]. For the *n*-letter-back, task performance [similarly defined as the mean difference between difficult (2- and 3-back) and easy (x- and 1-back) items] for the first subsession did not differ between groups ($2{\cdot}1 \pm 2{\cdot}9$ *v.* $2{\cdot}0 \pm 1{\cdot}9$, $F<1$), but for the second subsession, performance was again better in the high-dissociative group [$0{\cdot}36 \pm 3{\cdot}0$ *v.* $3{\cdot}0 \pm 2{\cdot}35$, $F(1, 19)=4{\cdot}8$, $p=0{\cdot}041$] than in the low-dissociative group. Reaction times did not differ in both tasks ($F<1$). Subjective levels of distress (SUD-S) scores were numerically higher in the high-dissociative group, but these differences were not significant (*n*-back, first subsession: $33{\cdot}0 \pm 19{\cdot}1$ *v.* $24{\cdot}0 \pm 14{\cdot}6$; second subsession: $30 \pm 19{\cdot}0$ *v.* $25{\cdot}6 \pm 16{\cdot}3$; Sternberg: $33{\cdot}5 \pm 26{\cdot}1$ *v.* $22{\cdot}3 \pm 18{\cdot}8$; all $F<1$). To exclude the possibility that performance differences during the Sternberg and *n*-back (second subsession) were due to differences in levels of distress, analyses of co-variance were performed with SUD-scores as co-variates. For the *n*-back (second session), group effects were still significant [$F(1, 19)=4{\cdot}9$, $p=0{\cdot}041$], whereas differences for the Sternberg were only marginally significant after regressing out SUD-scores [$F(1, 19)=3{\cdot}7$, $p=0{\cdot}074$].

Results for imaging data are summarized in Tables 1–3. Main effects for task load for the Sternberg task for each group were found in left dorsolateral and ventrolateral prefrontal cortex, left parietal cortex, left inferior posterior temporal cortex, supplementary motor area extending into anterior cingulate gyrus (ACG), and cerebellum. In addition, in the high-dissociative group, we found right DLPFC and right parietal cortex, whereas in the low-dissociative group, we found right fusiform gyrus (Table 1, Fig. 1). For the *n*-letter-back task, in both groups increasing task load was associated with activity bilaterally in DLPFC, VLPFC, and parietal cortex, as well as in right SMA,

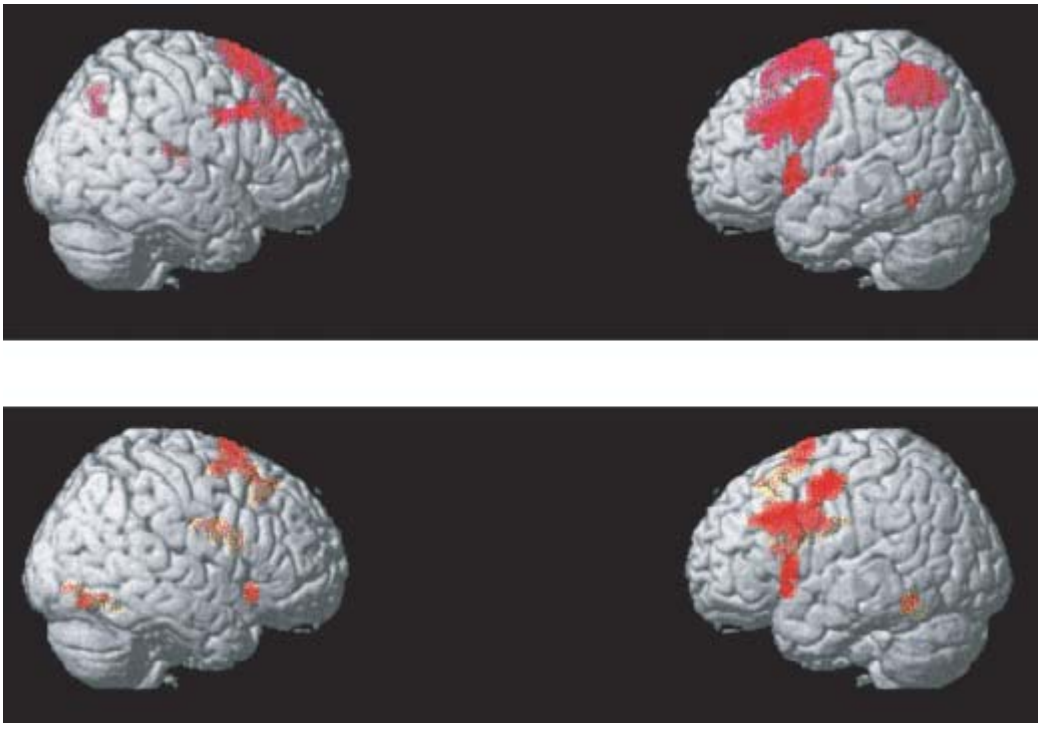

FIG. 1. Three-dimensional rendering of task-load-related activity during performance of the Sternberg task in high-dissociative (upper panel) and low-dissociative (lower panel) participants.

ACG, and cerebellum (Table 2, Fig. 2). Group × task-load interaction effects for both tasks were found in favour of the high-dissociative group in left posterior DLPFC; for the *n*-back, left parietal cortex was also identified. In contrast, group x task-load interaction effects in favour of the low-dissociative group were found only for the Sternberg, in bilateral fusiform gyrus and brain stem (Table 3).

We also investigated whether the increased task-load-related activity in the high-dissociative group was due to performance differences. To this end, we performed *post hoc* comparisons of the two subsessions of the *n*-letter-back task, because the high-dissociative group had performed slightly better than the low-dissociative group during the second subsession, but not during the first. We did not find any significant session-to-session differences for each group, however. Moreover, the task load × group interaction effects in favour of the high-dissociative group were found in both subsessions.

DISCUSSION

In the present study, we used fMRI to investigate neurophysiological correlates of verbal working memory in high- and low-dissociative participants. To this end, participants performed a parametric version of a verbal delayed match to sample task (Sternberg task), as well as a parametric *n*-letter-back task, while being scanned. Behavioural data demonstrated that high-dissociators performed better during the Sternberg task as well as during the second subsession of the *n*-letter-back task, whereas reaction times for both tasks were similar across groups. The Sternberg findings are in agreement with previous work indicating an increased working memory span in high-dissociative participants (De Ruiter *et al*. in press). However, our data indicate that high-dissociative participants may also perform better during a manipulation type WM task, in which memory span (stack size) is less important than efficiency

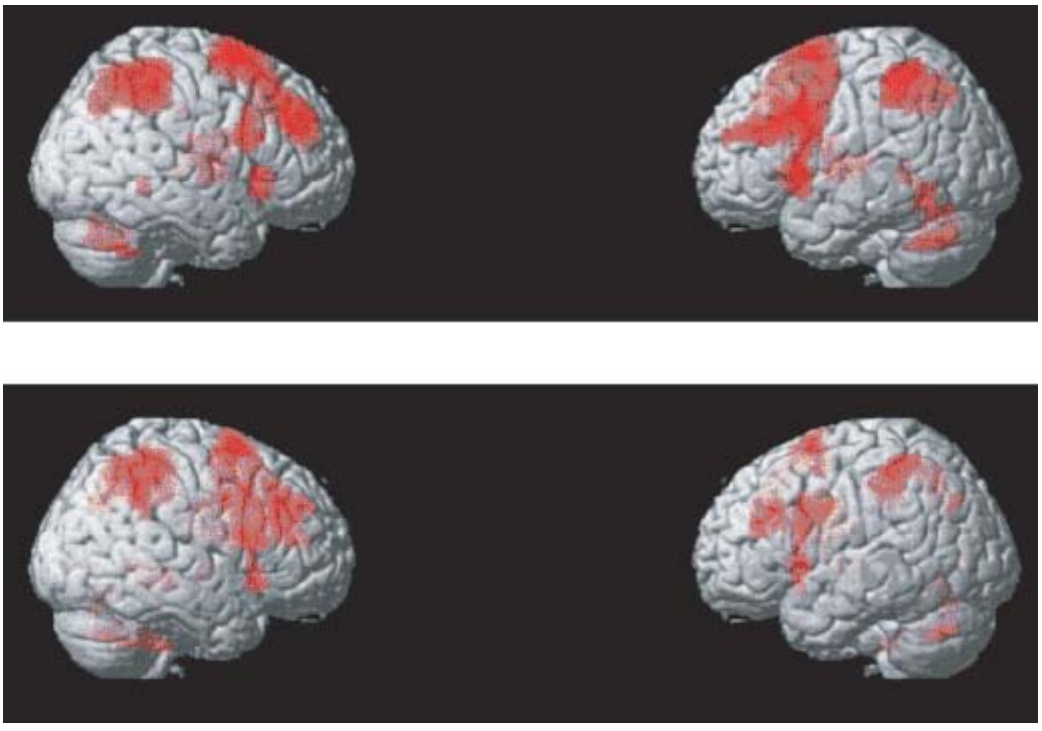

FIG. 2. Three-dimensional rendering of task-load-related activity during performance of the *n*-letter-back task in high-dissociative (upper panel) and low-dissociative (lower panel) participants.

of stack updating. WM-performance differences were not abolished after correcting for differences in subjective distress. This suggests that they are not due to catecholaminergic modulation of working memory (Arnsten, 1998), but are associated with fundamental differences in a general information-processing mechanism.

Imaging data revealed in both groups for the Sternberg task-load-related activity in L DLPFC, L parietal cortex, L inferior temporal cortex, as well as cerebellum and SMA, extending into ACG. In addition, we found R DLPFC and parietal cortex for high-dissociators, and right fusiform gyrus for low-dissociators. Group × task load-interaction effects were identified in L DLPFC in favour of the high-dissociative group, as well as in R fusiform gyrus and brain stem in favour of the low-dissociative group. For the *n*-back task, we found similar areas, although these tended to be bilateral for both groups, rather than left-lateralized: bilateral DLPFC and VLPFC, parietal cortex, SMA, and cerebellum. Group × task load-interaction effects in favour of the high-dissociative group were again found in left DLPFC, but also in L parietal cortex. Thus, both WM tasks activated highly similar networks across groups. In earlier WM studies, VLPFC has been found primarily in maintenance (delayed match to sample) tasks, whereas DLPFC was additionally activated during manipulation tasks, such as verbal (Braver *et al*. 1997) and spatial (Jansma *et al*. 2000) *n*-back, but also reordering/alphabetization (Postle *et al*. 1999), letter fluency, dual task *versus* single task performance, and planning tasks (van den Heuvel *et al*. 2003). Therefore, it has been postulated that VLPFC is engaged in maintenance proper (including subvocal rehearsal), and DLPFC in selection/manipulation/monitoring of WM contents (Fletcher & Henson, 2001). An alternative hypothesis has been put forward by Duncan and Owen (2000), who concluded that mid-ventrolateral, mid-dorsolateral, and dorsal cingulate regions were consistently recruited for solving diverse cognitive problems. Regional specialization, in their view, is a matter of degree rather than kind, such as left-lateralization of verbal,

Table 2. *Areas showing significant ($p<0{\cdot}005$ corrected, extent threshold >10 voxels) linear task-load-related increase in activity during performance of the n-letter-back task in high- and low-dissociative subjects*

	High-dissociation group ($n=10$)			Low-dissociation group ($n=11$)		
Region	Talairach coordinates	*Z* score	BA	Talairach coordinates	*Z* score	BA
L prefrontal						
Anterior	−36, 45, 24	4·4	10			
	−45, 39, 27	4·3	9	−42, 39, 30	4·0	9
Dorsolateral	−48, 33, 21	4·7	46	−45, 36, 21	4·4	46
	−48, 24, 27	5·0	9	−45, 27, 33	4·1	9
	−51, 12, 36	5·5	9	−51, 9, 36	4·6	9
Ventrolateral	−54, 12, 15	4·3	44	−51, 12, 18	4·5	44
	−51, 12, 3	4·8	45	−51, 12, 3	4·2	45
	−36, 15, 3	5·3	45	−36, 15, 3	4·4	45
R prefrontal						
Anterior	33, 45, 18	3·9	10	33, 42, 15	4·4	10
Dorsolateral	45, 39, 30	5·2	9	42, 42, 30	4·2	9
				45, 33, 36	4·4	9
	48, 15, 30	3·9	44	54, 15, 36	4·6	44
Ventrolateral	54, 12, 18	4·1	44	57, 12, 15	4·6	44
L parietal	−45, −42, 51	5·4	40	−45, −39, 51	5·4	40
	−30, −48, 48	5·4	40	−30, −54, 51	4·4	40
R parietal	36, −48, 51	5·8	40	36, −48, 51	5·6	40
	45, −39, 51	5·3	40	45, −39, 54	5·5	40
Anterior cingulate gyrus	6, 27, 39	5·0	32	6, 27, 39	4·6	32
SMA	21, 6, 63	5·5	6	21, 6, 63	5·7	6
Cerebellum	−21, −69, −33	3·9		−21, −63, −39	4·5	
	39, −51, −42	4·6		39, −51, −42	4·2	

BA, Brodmann area; SMA, supplementary motor area.

Table 3. *Areas showing task load by group interactions ($p<0{\cdot}001$ uncorrected, masked with main effects for task load at $p<0{\cdot}001$ uncorrected) for the Sternberg task and n-letter-back task in high- and low-dissociative subjects*

	Sternberg task			*n*-letter-back task		
Region	Talairach coordinates	*Z* score	BA	Talairach coordinates	*Z* score	BA
	High-dissociation > low			High-dissociation > low		
L prefrontal						
Dorsolateral	−33, 9, 36	4·7	9	−36, 9, 36	3·0	9
L parietal				−30, −48, 48	3·1	40
	High-dissociation < low			High-dissociation < low		
R fusiform gyrus	36, −63, −12	4·2	19			
	33, −45, −15	3·8	37			
Brain stem	9, −30, −36	3·4				

BA, Brodmann area.

as opposed to spatial/object, WM tasks. The present data appear to be in line with this second model, as they do not clearly support the hypothesis of a maintenance/manipulation segregation between VLPFC and DLPFC (see Veltman *et al.* 2003, for a more extensive discussion of this issue).

An important finding of the present study is that in both tasks, high dissociative participants showed greater task-load-related activity in the same region, i.e. L middle DLPFC. Moreover, this difference cannot be explained solely by the superior performance of the high-dissociative groups. Although it has been shown that

performance during a maintenance task is associated with signal strength during the encoding/delay phase (Pessoa *et al*. 2002), in the present study we found these group differences in both subsessions of the *n*-letter-back task, whereas performance scores were different only during the second subsession. Therefore, it appears that, although both groups rely on similar networks to perform these WM tasks, the high-dissociative group activates this system to a greater extent. In the present study, we found two additional areas showing group $\times$ task interaction effects: L parietal cortex in high-dissociative compared with low-dissociative participants (*n*-back), and R fusiform area in low-dissociative compared with high-dissociative participants (Sternberg task). Left parietal cortex has previously been implicated in phonological storage (Paulesu *et al*. 1993), but has also been found in manipulation WM tasks, which has been interpreted as participation in executive functioning (Cohen *et al*. 1997; Collette *et al*. 1999), or due to increased attentional demands at higher task loads (Honey *et al*. 2000). The greater involvement of R fusiform gyrus in low dissociative participants during performance of the Sternberg task suggests stronger visual (object) processing in this group. It is unclear whether this is due to decreased visual selective attention resulting from a higher *relative* WM load in the low-dissociative group, as would be predicted by the findings of de Fockert and colleagues (2001), or to a fundamental difference in information-processing style (e.g. verbal *versus* non-verbal style; Gevins & Smith, 2000).

The present results seem to contradict the conjecture by Dorahy (2001) of potential deficits in working memory with dissociative patients. Though unlikely, it remains, however, possible that only patients are characterized by working memory deficits, but high-dissociative non-pathological individuals have elevated working memory abilities. An alternative view that visuo-spatial, but not verbal, working memory is affected in high levels of dissociative style, both pathological and non-pathological, can also not be excluded on the basis of these results. The main finding of this study, increased working memory performance as a function of dissociative style, is, however, not easy to reconcile with Dorahy's suggestion. In our view, moreover, it corresponds closely to other findings in the fields of attention and memory. Words that are, for instance, kept active longer in working memory are generally encoded more strongly in episodic memory (e.g. Raaijmakers & Shiffrin, 1981), which also offers a potential explanation for the findings of enhanced memory performance by high dissociators (Cloitre *et al*. 1996; McNally *et al*. 1998, 2001; Elzinga *et al*. 2000). Only with 'alter' changes clear episodic memory deficits have been obtained in dissociative patients (Eich *et al*. 1997; Elzinga *et al*. 2003). This, probably, does not indicate that working memory capacity changes with 'alter', but suggests that the working memory ability is actively engaged to suppress 'unwanted' memories in the other 'alter'. The retrieval inhibition hypothesis for inter-alter memory performance was supported by the finding of a directed forgetting effect in a second 'alter' that could not be caused by differential storing by the first 'alter' (Elzinga *et al*. 2003). Apart from its potential for explaining dissociative disorders, dissociative style also provides an opportunity to investigate general information-processing mechanisms in healthy individuals. Strictly speaking, because our study only concerned a non-clinical sample, our conclusions should only address non-pathological functioning. We feel that sufficiently converging and consistent results have been obtained in the fields of attention, WM, and long-term memory to conclude that (at least) non-pathological dissociative tendencies correspond to both enhanced attentional and working memory abilities, which have a strong genetic basis (Jang *et al*. 1998). A differentiation between high- and low-dissociative individuals in experiments on attention and memory may in the end result in a sharper delineation of the elementary processes involved.

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DECLARATION OF INTEREST

None.

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